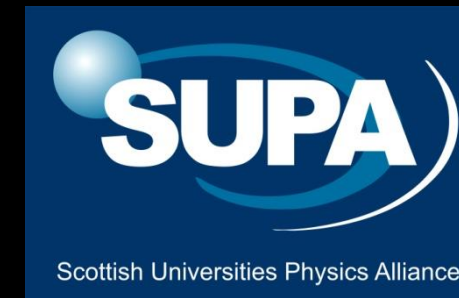


University of
St Andrews

Towards a BEC rotation sensor

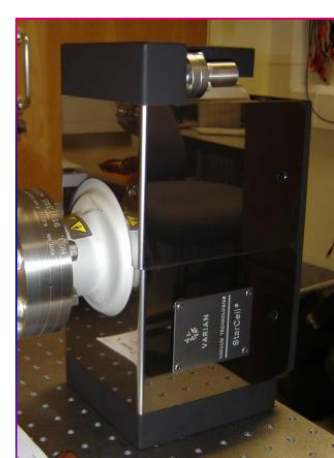
D. Bowman, P. Ireland, L.A. Lee, G.D. Bruce, D. Cassettari

Cold Atoms Group, SUPA School of Physics and Astronomy,
University of St Andrews, North Haugh, St Andrews, Fife, KY16 9SS, UK
www.st-andrews.ac.uk/coldatoms



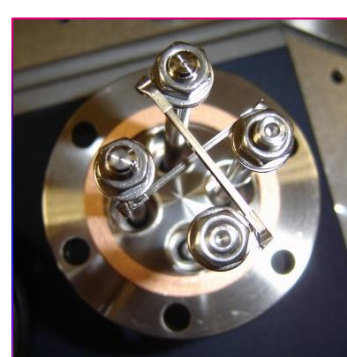
Experimental Setup

The aim of the experiment is to create and study a Rubidium Bose-Einstein Condensate (BEC) in a ring trap. The superfluidity of the BEC leads to quantised jumps in its angular momentum, such that a high sensitivity to rotation can be achieved. The first step to achieve this goal is to generate a BEC using an Ultra High Vacuum (UHV) chamber and a multitude of cooling techniques. The second step is to produce a ring trap geometry with a Spatial Light Modulator (SLM) overlapped with a light sheet, and to trap the atoms in this optical trap. Initial tests of the rotation sensor will be performed by stirring the BEC within the ring.



Ion Pumps

Two ion pumps are used in the system. The first will produce a high vacuum ($\sim 10^{-8}$ Torr) in the loading chamber, whilst the second will lead to ultra high vacuum ($\sim 10^{-11}$ Torr) in the experiment chamber.



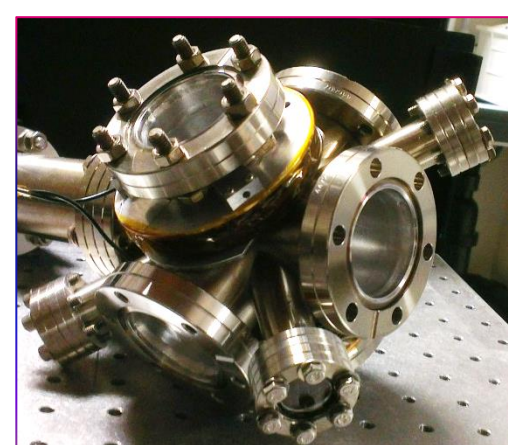
Rubidium Dispenser

Our isotope of choice is Rubidium-87 (^{87}Rb). The dispenser allows for ^{87}Rb atoms to be fed into the loading chamber.



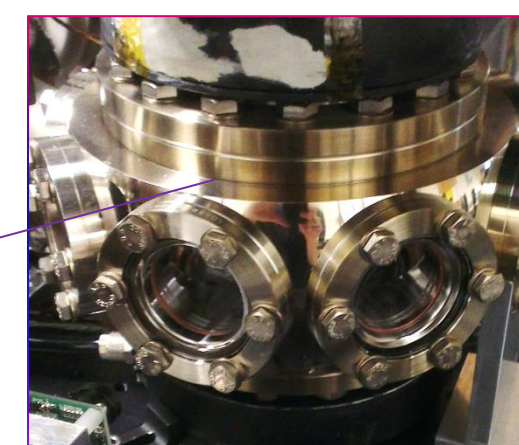
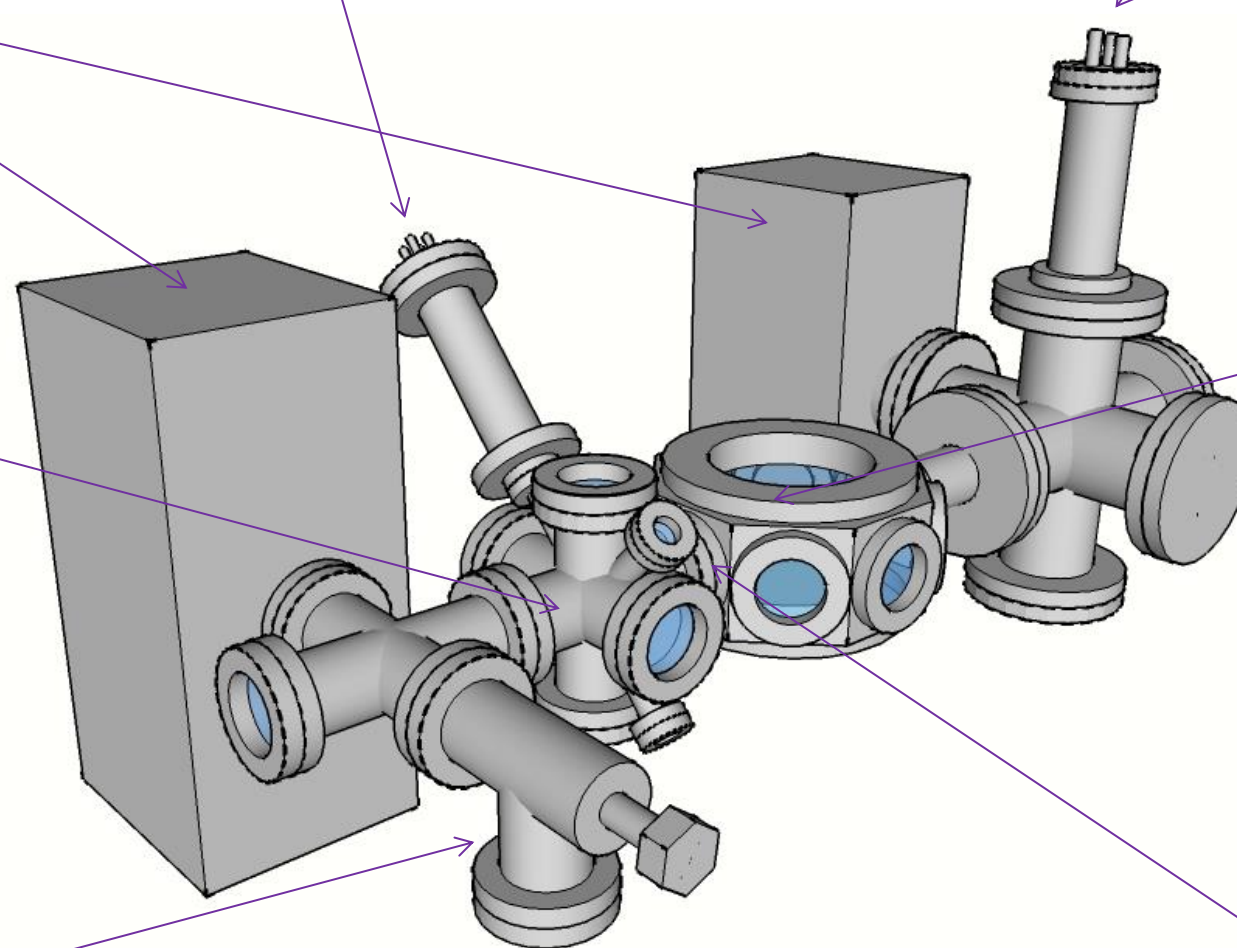
Titanium Sublimation Pump

A titanium filament inside the chamber is heated up by passing a high current through it ($\sim 50\text{A}$). This releases the titanium into the chamber which sticks to the walls. Molecules inside the chamber will then stick to the titanium-coated walls.



Loading Chamber

The loading chamber will house the 2D Magneto-Optical Trap (MOT). Since the vacuum pressure in this chamber will be much higher than the experiment chamber, the MOT will allow for a large number of cold ^{87}Rb atoms to be sent through into the experiment chamber. The loading chamber and experiment chamber are connected via a differential pumping tube



Experiment Chamber

The experiment chamber will house a 3D Magneto-Optical Trap (MOT). Further cooling of the atoms will also take place, as well as the rotation-sensing experiments.

Experimental stages after the MOT will be: Optical molasses $\rightarrow$ Magnetic trap $\rightarrow$ Radio frequency evaporation $\rightarrow$ Hybrid trap $\rightarrow$ Optical dipole ring trap pattern overlapped with a light sheet.

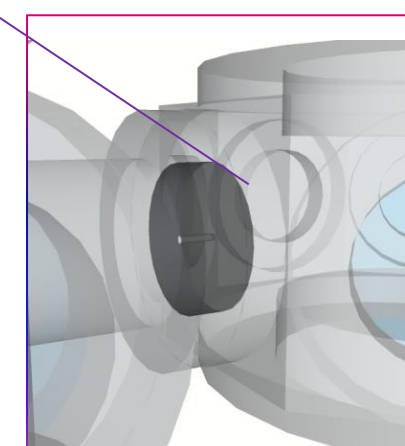


All-Metal Right-Angle Valve

The valve allows for a turbo molecular pump to be connected/disconnected without breaking vacuum. The turbo pump produces a vacuum pressure low enough for the ion pumps and titanium sublimation pump to operate.

Double Chamber Vacuum Setup

In the first, higher pressure, chamber a 2D-MOT and push beam create a high-flux atom source, which traverses a differential pumping section before loading a second MOT in a UHV vacuum chamber, where science experiments will also take place.

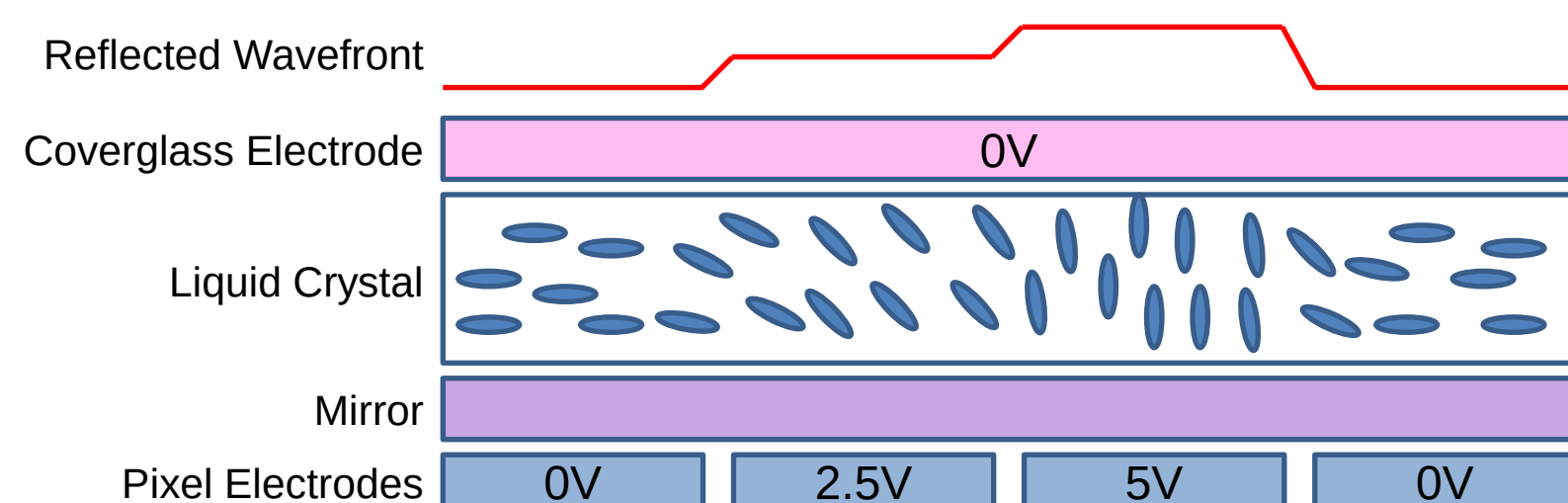


Differential Pumping Tube

A narrow tube between the experiment chamber and loading chamber will allow the push beam to drive ^{87}Rb atoms from the 2D MOT into the 3D MOT, and maintains the three-order of magnitude pressure differential.

Creating a Ring Trap Pattern

The ring trap will be generated with a **Spatial Light Modulator (SLM)**. The SLM has a liquid crystal and pixel electrodes. By applying a voltage to the electrodes, the molecules in the crystal rotate. These rotations cause the path length of the light through the molecule to change, which causes phase retardation and thus the SLM acts as a phase mask.



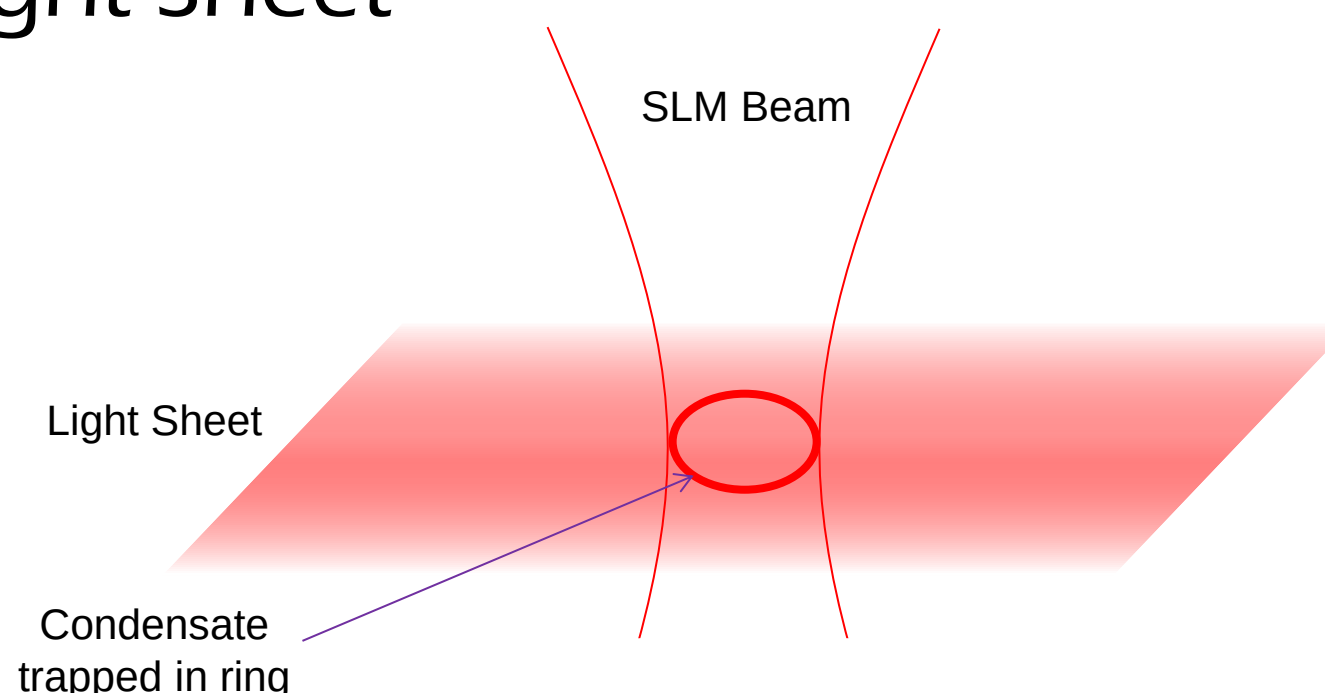
The SLM has 256×256 pixels, where each pixel can impart 256 distinct values of phase between 0 and 2π . Thus an arbitrary phase pattern can be applied to a light beam, which can then be passed through a lens to form an intensity pattern which is proportional to the Fourier transform of the phase pattern.



Through iterative and feedback processes, the correct phase for a ring geometry, as well as a ring with "stirring rods", has been determined, and the light patterns successfully generated in our lab.

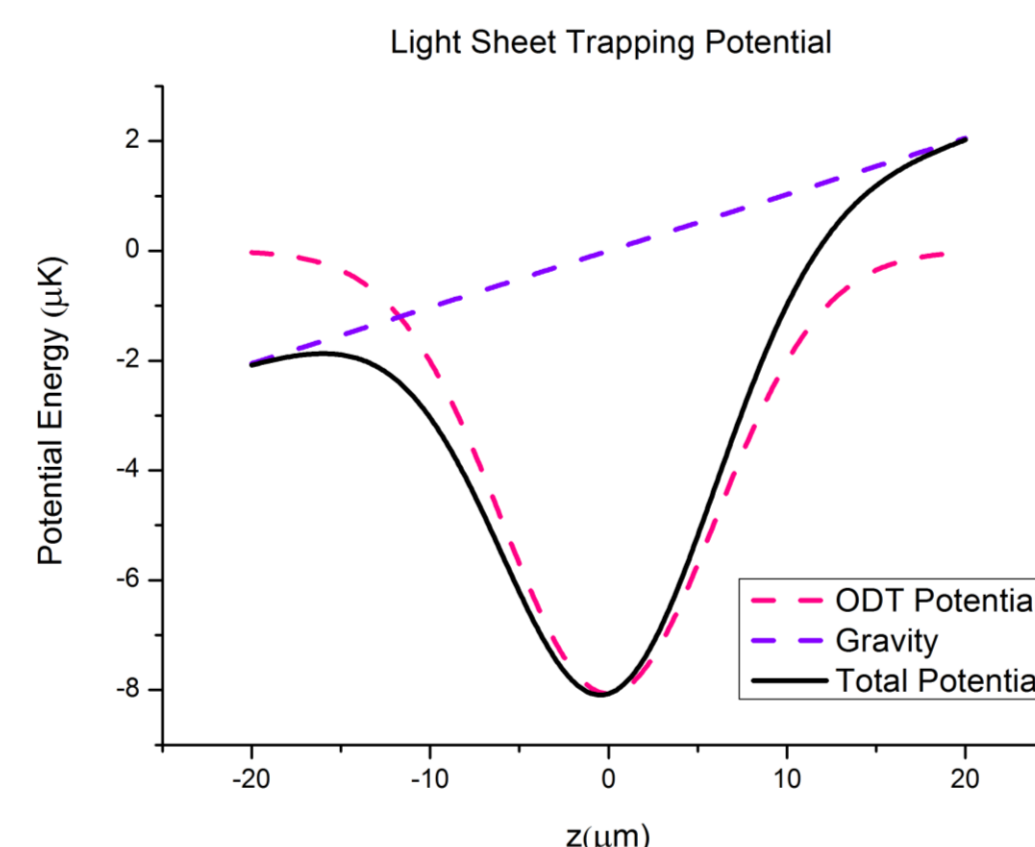
G.D. Bruce, et al., Phys. Scr. **T143** 014008 (2011)

Light Sheet



The SLM beam will overlap with a light sheet, providing confinement of the condensate in all three dimensions. The light sheet is produced by a cylindrical lens which focuses the beam only in one axis. Tight vertical confinement and high power in the light sheet will be necessary to hold the atoms against gravity. A 1.5W Nd:YVO_4 laser will provide the needed power to both the SLM and sheet.

The light sheet will have a $1/e^2$ half width in the vertical (horizontal) direction of $12\mu\text{m}$ ($300\mu\text{m}$). The trap depth produced for a 300mW beam of these dimensions is $\sim 6\mu\text{K}$, which will be accessible after evaporative cooling. In order to produce a beam with these dimensions, three cylindrical lenses will be necessary.



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